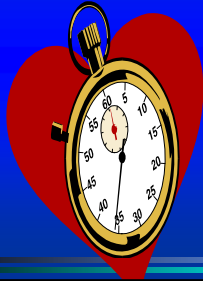


Advances in the imaging of chest pain patients in the ED



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Objectives:

- Know cardiac imaging modalities and terminology
- Learn traditional stress testing, and newer imaging techniques
- Know variables associated with imaging selection

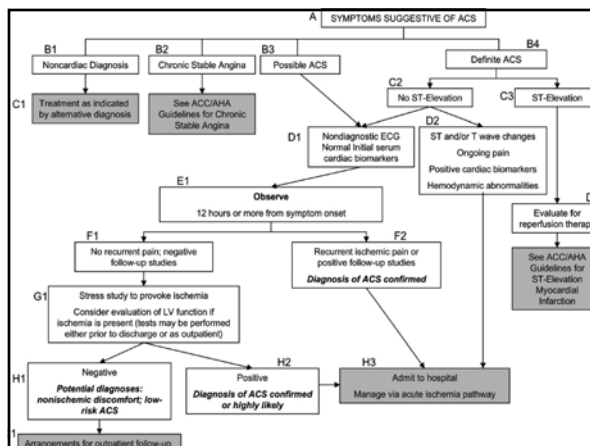
Background

- Cardiac ischemia:
 - High risk: CV disease = 32% of U.S. deaths
 - High volume: “Chest pain” = 5.3% of ED visits
 - High liability: Missed MI = 2.3% (0-11%)
- Why “Missed MI”:
 - History: 33% do not have “chest pain”
 - ECG: 35% non-diagnostic, 8% “normal”!
 - Cardiac markers: 44% normal on ED arrival

Is it enough to simply “rule-out MI”?

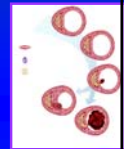
Trappe K, Jackson RE, Ross M. Ann Emerg Med 2003; 42:58.

- 108,734 ED visits:
 - 2716 CPOU (2.5%)
 - 353 CPOU admitted (13%)
 - 35 (10%) serious non-ACS pathology
 - 131 ACS (37%), diagnosed by:
 - » Stress imaging: 75 (57%)
 - » Stress ECG alone: 4 (3%)
 - » Serial cardiac markers: 25 (19%)
 - » Clinical deterioration: 10 (8%)
 - » Physician discretion: 5 (4%)



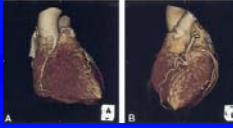
Acute Coronary Syndromes

- The tale of three coronaries:
 - Normal, plaque (CAD), ruptured plaque (ACS)
- Leading to three levels of disease:
 - STEMI, NSTEMI, UA
- Anatomy vs. Physiology:
 - Anatomy - >70% coronary occlusion
 - Physiology – oxygen supply/demand mismatch
 - Ischemic symptoms, ECG changes, stunned myocardial cell membranes, wall motion abnormalities

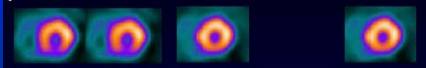


Overview: Non-stress Imaging Modalities

- Coronary CTA = Anatomy



- Rest sestimibi Imaging = Physiology



Overview – Stress Testing and Imaging:

Stress Modalities:

- Ischemia induction
 - Graded Exercise Stress Test
 - Dobutamine ST
- Vasodilators
 - Adenosine
 - Dipyrimadole (*Persantine*)
 - Regadenoson (*Lexiscan*)

Stress Imaging:

- Echo – rest / stress
- Nuclear
 - SPECT (Camera)
 - Thallium
 - Technecium (Tc 99m)
 - Tc Sestimibi (*Cardiolite*)
 - Tc tetrofosmin (*Myoview*)
 - PET (Camera)
 - Rubidium
- MRI

Stress Testing and Imaging Combinations

Stress Modalities:

- Ischemia induction
 - Graded Exercise Stress Test
 - Dobutamine ST
- Vasodilators
 - Adenosine
 - Dipyrimadole (*Persantine*)
 - Regadenoson (*Lexiscan*)

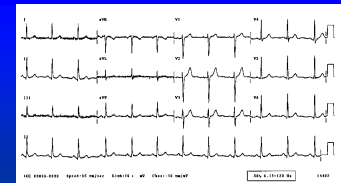
Stress Imaging:

- Echo – rest / stress
- Nuclear:
 - SPECT (Camera)
 - Thallium
 - Technecium (Tc 99m)
 - Tc Sestimibi (*Cardiolite*)
 - Tc tetrofosmin (*Myoview*)
 - PET (Camera)
 - Rubidium
- MRI

Case #1

- 45 year old male smoker with hyperlipidemia.

- Presenting with epigastric and midsternal chest “discomfort” (not pain) radiating to the neck. Associated with sweats and dyspnea. Relieved by antacids. . .
- A “normal stress test” in the office one month ago:
 - “No ST changes at 65% PMHR”
- Normal exam
- ECG:



- Dispo?

First, let's understand exercise testing!

- Test selection
- Test performance
- Interpretation
- Limitations

Physiology of exercise testing

- Energy expenditure:
 - 1 MET (metabolic equivalent) =
 - The resting homeostatic requirement
 - 3.5 ml O₂/kg/min
 - Roughly 1.2 cal/min
- Oxygen consumption:
 - VO₂ max = HR x SV x A-VO₂ difference
- Oxygen supply mismatch:
 - coronary ischemia – 3 MEASURES
 - Clinical
 - Hemodynamic
 - ECG changes

TABLE 2. Absolute and Relative Contraindications to Exercise Testing

Absolute

- Acute MI (within 2 days)
- High-risk unstable angina
- Uncontrolled cardiac arrhythmias causing symptoms of hemodynamic compromise
- Active endocarditis
- Symptomatic severe aortic stenosis
- Decompensated symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute noncardiac disorder that may affect exercise performance or be aggravated by exercise (eg, infection, renal failure, thyrotoxicosis)
- Acute myocarditis or pericarditis
- Physical disability that would preclude safe and adequate test performance
- Inability to obtain consent

Complications of exercise testing

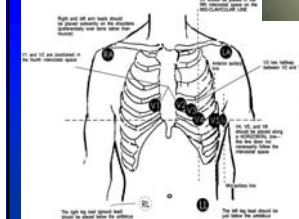
TABLE 1-2. Complication Rates of Exercise Testing (1969–1995)

Investigator (ref. #)	Number of Tests	Morbidity Rate (per 10,000)	Mortality Rate (per 10,000)	Total Complications (per 10,000)	Physician Supervised?
Rochmis & Blackburn (13)	170,000	2.4	1.0	3.4	Yes*
Stuart & Ellestad (14)	518,448	8.4	0.5	8.9	Yes*
Scherer & Kaltenbach (16)	353,638*	0	0	0	Yes*
	712,285*	1.4	0.2	1.6	Yes*
Young et al. (15)	1,377*	232	0	232	Yes*
Atterhog et al. (17)	50,000	5.2	0.4	5.6	Yes*
Cahalin/Blessey (19,20)	18,707	3.8	0.9	4.7	No
DeBusk (22)	>12,000	—	2.5	—	No
Gibbons et al. (18)	71,914	0.7	0.1	0.8	Yes*
Lem et al. (21)	4,050	0.3	0	0.3	No
Knight et al. (23)	28,133	3.2	0	3.2	No
Franklin et al. (24)	58,047	2.1	0.3	2.4	No

American College of Sports Medicine's guidelines for exercise testing and prescription, sixth edition, senior editor Barry Franklin, 2000. Lippincott, Williams, and Wilkins, Baltimore, Maryland.

Setting up the Graded Exercise Test

12-lead ECG Electrode Placement



FUNCTIONAL CLASS	CLINICAL STATUS	O ₂ COST ml/kg/min	METS	BICYCLE ERGOMETER	TREADMILL PROTOCOLS	METS	
NORMAL AND I	HEALTHY, DEPENDENT ON AGE, ACTIVITY			1 WATT • 6.1 kg/min	BRUCE MODIFIED 3 min Stages MPH %GR	BRUCE 3 min Stages MPH %GR	NAUGHTON
				FOR 10 KG BODY WEIGHT kg/min	6.0 22 6.0 22	5.5 20 5.0 20	
					5.0 18 5.0 18		
				56.0 16			16
				52.5 15			15
				49.0 14	1500		14
				45.5 13		4.2 16 4.2 16	13
				42.0 12	1350		12
				38.5 11	1200		11
				35.0 10	1050	3.4 14 3.4 14	10
				31.5 9	900		9
				28.0 8	750		2 17.5 8
24.5 7		2.5 12 2.5 12	7				
21.0 6	600		2 10.5 6				
17.5 5	450	1.7 10 1.7 10	2 7.0 5				
14.0 4	300		2 3.5 4				
10.5 3	150	1.7 5	2 0 3				
7.0 2		1.7 0	2 0 2				
3.5 1			1 0 1				

Treadmill stress testing

STANDARD BRUCE				
STAGE	DURATION (min)	TOTAL TIME	SPEED (mi/hr)	GRADE (%)
1	3		1.7	10
2	3	6	2.5	12
3	3	9	3.4	14
4	3	12	4.2	16
5	3	15	5.0	18
6	3	18	6.0	20

MODIFIED BRUCE				
STAGE	DURATION (min)	TOTAL TIME	SPEED (mi/hr)	GRADE (%)
1	3		1.7	0
2	3	6	1.7	5
3	3	9	1.7	10
4	3	12	2.5	12
5	3	15	3.4	14
6	3	18	4.2	16
7	3	21	5.0	18

- The standard treadmill is motor driven. Speed and gradient (steepness) can be varied.
- The most commonly used protocols are the Standard Bruce and the Modified Bruce.
- Endpoint is usually "symptom - limited"

Exercise test reported outcomes: "Symptom - limited" test

Electrocardiographic

- Maximum ST depression
- Maximum ST elevation
- ST-depression slope (downsloping, horizontal, upsloping)
- Number of leads showing ST changes
- Duration of ST deviation into recovery
- ST/HR indexes
- Exercise-induced ventricular arrhythmias
- Time-to-onset of ST deviation

Hemodynamic

- Maximum exercise heart rate
- Maximum exercise systolic blood pressure
- Maximum exercise double product (HR x BP)
- Total exercise duration
- Exertional hypotension (drop below preexercise value)
- Chronotropic incompetence

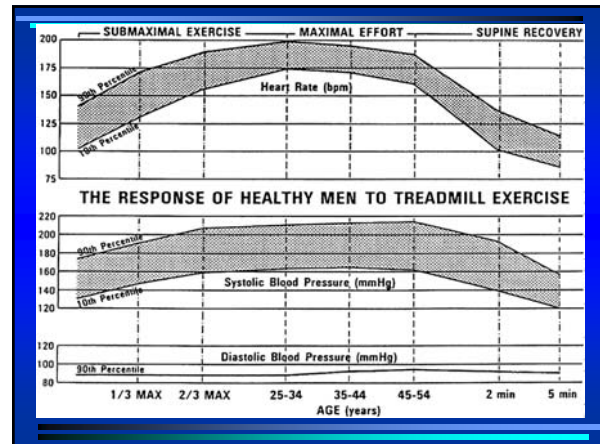
Symptomatic

- Exercise-induced angina
- Exercise-limiting symptoms
- Time to onset of angina

HR indicates heart rate; and BP, blood pressure.

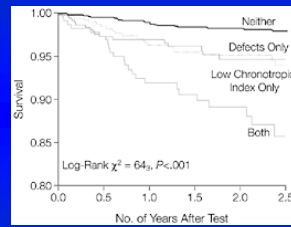
Indications for stopping a GXT

- Goal – 85% age predicted max HR
- Absolute indications
 - >1mm ST elevation (other than V1 or aVR)
 - Drop in SBP >10mm Hg with evidence of ischemia despite workload increase
 - Moderate to severe angina
 - CNS symptoms
 - Signs of poor perfusion
 - Sustained V. tach
 - Technical difficulties monitoring the patient
 - Patient's request to stop



Chronotropic incompetence

- Attenuated heart rate response to exercise
 - <85% age adjusted max HR
- Greater risk of death over 2 yrs
 - Independent of age, sex, thallium perfusion defects, and other confounders:
 - Adjusted risk = 1.84
 - Independent of "Chronotropic index" which corrects for age and fitness:
 - Adjusted risk = 2.19



Survival as a Function of Chronotropic Index and Presence or Absence of Thallium Perfusion Defects
Lauer M, et al. JAMA. 1999;281:524-529

Sensitivity, specificity, and predictive accuracy of exercise stress testing

Meta-Analyses of Exercise Testing^{25,26}

Grouping	Number of Studies	Total Number of Patients	Sens (%)	Spec (%)	Predictive Accuracy (%)
Meta-analysis of standard exercise test	147	24,047	68	77	73
Meta-analysis without MI	58	11,691	67	72	69
Meta-analysis without workup bias	3	> 1000	50	90	69
Meta-analysis with ST depression	22	9153	69	70	69
Meta-analysis without ST depression	3	840	67	84	75
Meta-analysis with digoxin	15	6338	68	74	71
Meta-analysis without digoxin	9	3548	72	69	70
Meta-analysis with LVH	15	8016	68	69	68
Meta-analysis without LVH	10	1977	72	77	74

Sens indicates sensitivity; Spec, specificity; MI, myocardial infarction; and LVH, left ventricular hypertrophy.

Stress testing patients through the ED: "chest pain center patients"

Author	# pts	Morbidity	Outcome
Tsakonis (1991)	28	None	SAFE
Kerns (1993)	32	None	SAFE Less cost
Gibler (1996)	1,010	None	Sens= 29% Spec= 99.4% PPV = 44% NPV = 98.7%
Gomez (1996)	100	None	SAFE Less cost
Zalenski (1998)	317	None	Sens= 90% Spec= 50% NPV = 98%
Polanczyk (1998)	276	None	Sens= 73% Spec= 74% NPV = 98%
Farkouh (1998)	424	None	Effective Less cost

How does this relate to our patient?

- Can we send him home with antacids?
- What was wrong with his stress test?
- What options are available?
 - Repeat stress test?
 - Stress test with imaging?
 - Imaging alone?
 - Cath?

Stress Imaging - Nuclear

- **Radiopharmaceuticals:**
 - Potassium analogs:
 - Thallium-201
 - Rubidium-82
 - Technetium-99m labeled agents:
 - Tc-99m-sestamibi
 - Tc-99m-tetrofosmin
 - Tc-99m-teboroxime

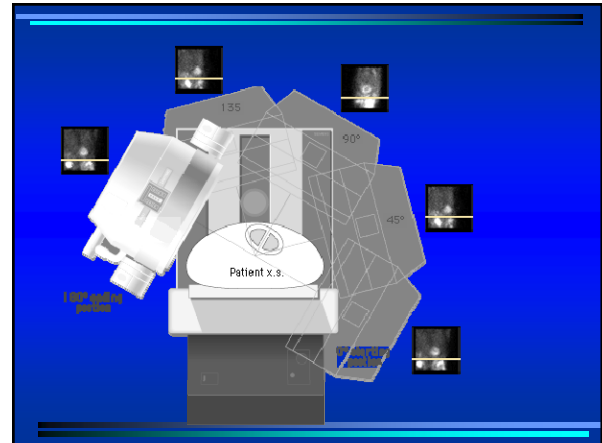
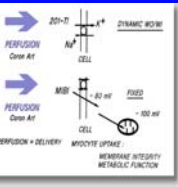
Thallium

- Biologically, the hydrogenated Tl⁺ ion is the size of potassium ions (K⁺) and behave biologically like K⁺.
- It enters cells quickly via the Na/K pump, and becomes part of the intracellular K pool.
- **ADVANTAGE WITH TL**
 - Long accumulated experience
- **DISADVANTAGE WITH TL**
 - Rapidly redistributes:
 - Patients must be imaged very soon after injection
 - Not practical for ER "STAT" rest imaging
 - Energy not optimal for gamma camera's. Inferior Image Quality

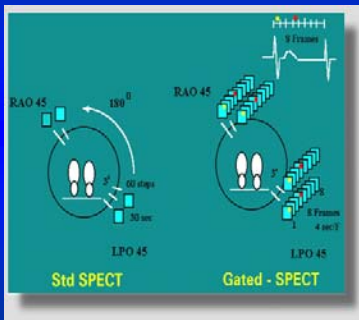
Technetium – Sestamibi (Cardiolyte)



- Crosses the cell membranes passively; via the cells' negative membrane potential
- Once intracellular it accumulates in the mitochondria.
- **ADVANTAGE WITH SESTAMIBI**
 - NO significant redistribution over 3 hours
 - Higher dose can be used for better image quality
 - Produced from kit - readily available
- **DISADVANTAGE WITH SESTAMIBI**
 - Global shortage presently
 - Eliminated by the liver - artifact problems

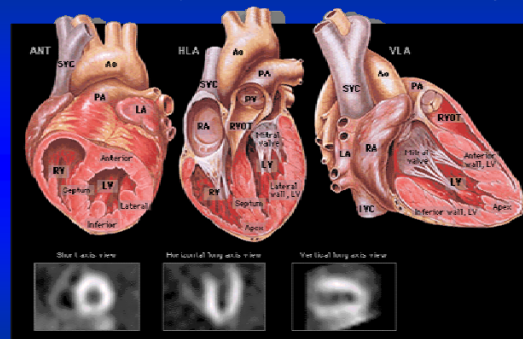


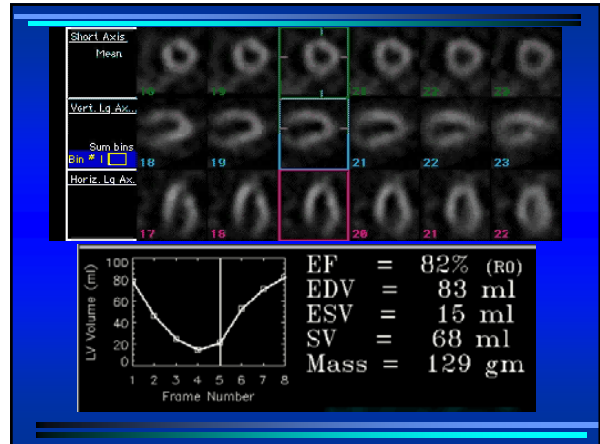
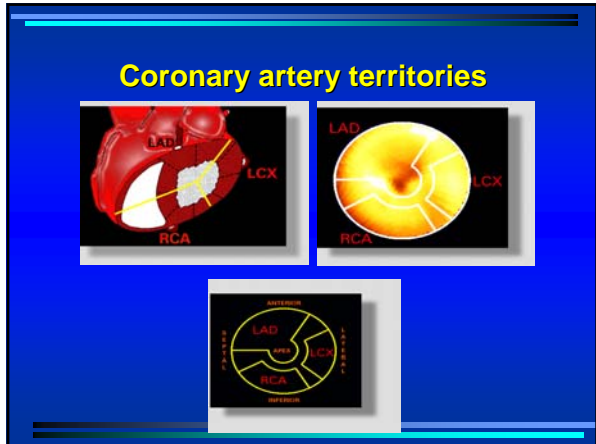
Gated SPECT - an acquisition technique where the patients ECG is used to guide image acquisition



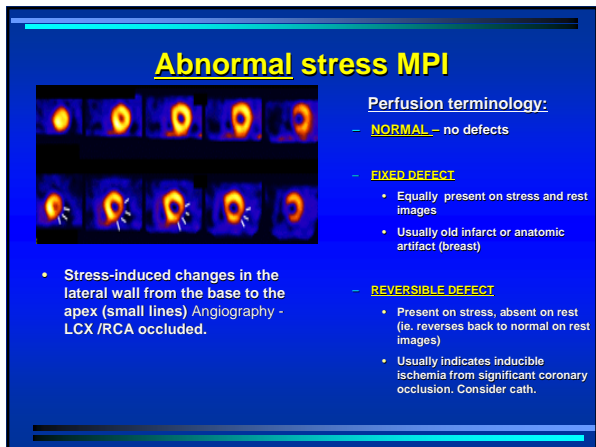
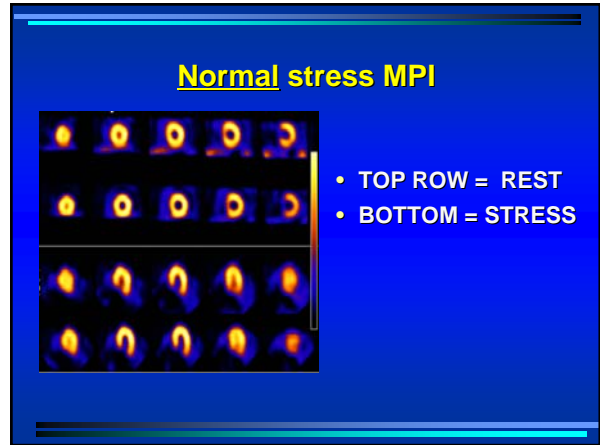
- Shows wall motion and ejection fraction
- Corrects for anatomic artifacts

Cardiac anatomy as seen in SPECT nuclear imaging





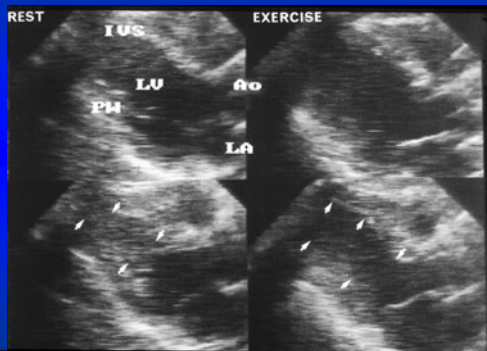
- ## “One Day” Nuclear Protocols
- **“REST-STRESS”** PROTOCOL (2-4 hours)
 - 8 mCi at REST24 mCi at peak STRESS imaging after 30-60 min
 - Allows big dose for stress imaging
 - **“STRESS - REST”** PROTOCOL (2-4 hours)
 - 8 mCi at peak STRESS24 mCi at REST imaging after 30-60 min
 - Don't need rest if stress is negative
 - **KEY POINT:**
 - In all one-day protocols the second dose must be "strong" enough (2 ½ - 3 times) to overpower what is left of the first dose!



Positron Emission Tomography (PET)

- **Rubidium Isotope**
 - Potassium analog (like TI)
- **Short half life (generator required)**
- **Coincidence unit** -
 - Excellent for artifact elimination (obesity)

Stress Imaging - Echocardiography



Echocardiography versus Nuclear Imaging in the ED

Sensitivity and Specificity of Acute Imaging^a

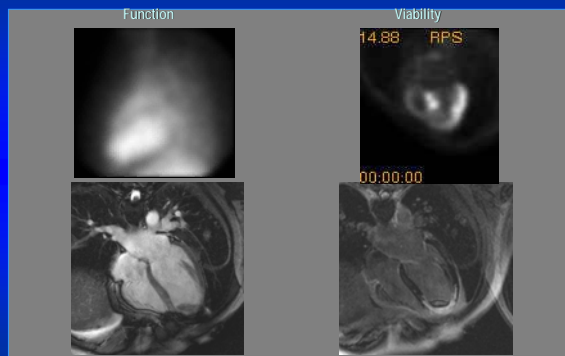
	Sensitivity (%)		Specificity (%)	
	Echocardiography	Perfusion Imaging	Echocardiography	Perfusion Imaging
MI	100 (65-100)	100 (65-100)	84 (78-89)	86 (80-91)
MI or PTCA	100 (75-100)	100 (75-100)	86 (80-91)	89 (81-94)
MI or SIDs ^b	88 (60-98)	80 (55-96)	50 (26-78)	48 (24-76)
MI, SigDIs ^b , or positive stress	75 (53-89)	75 (53-89)	88 (60-98)	90 (83-96)

^a Numbers in parentheses are 95% C.I. Sensitivities & specificities of echocardiography & myocardial perfusion were not significantly different.

^b Significant disease

Paventi et al. Resuscitation 2001;49:47

MRI vs Nuclear???



MRI imaging - "MUGA ON STEROIDS"

- **Pros:**
 - Much greater detail
 - Sensitivity / specificity comparable to nuclear
 - No radiation
- **Cons**
 - Limited experience and availability
 - Expensive
 - No proven advantage over nuclear / echo

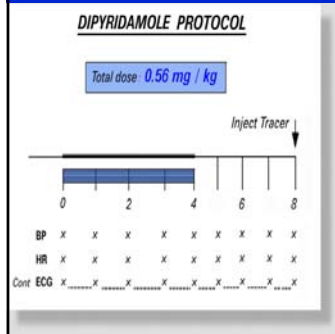
Case #2

- 70 year old female with diabetic neuropathy presents with transient dyspnea and left arm discomfort.
- Exam - wheel chair bound
- ECG: LBBB
- Negative serial cardiac markers

Pharmacological stress testing

Persantine	Adenosine	Dobutamine
Indirect Vasodilator	Direct Vasodilator	Demand / Supply
Block Adenosine Uptake	Stim Adenosine Receptor	Alpha / Beta agonist
Std. dose 0.56 mg/kg/4'	Titrated: 50 microg/kg/min → 140 microg/kg/min	Titrated: 5 microg/kg/min → 40 microg/kg/min + Atropine
High dose 0.84 mg/kg/4'	1/2 20 sec Aminophylline	1/2 2 min Beta-blockers /NTG
1/2 20 min Aminophylline / NTG	Conduction Abn. 10%	Arrythmias 30% BP fall 20%
Protracted CP Pulmonary Symp. BP fall 2%	Minor symptomatic 75% Headache 18% Flushing Shortness of breath	Minor symptomatic 35% Pounding Dyspnea 12% Anxiety / tremor

Persantine / Adenosine stress testing



- Dipyridamole / Adenosine
- Dilate coronary arteries
 - Fixed stenosis does not dilate - creating a perfusion defect by a "steal" phenomenon
 - Only with nuclear imaging
 - Both drugs are probably equally effective.
- Dipyridamole
- Well suited for patient with **LBBB**
 - The false positive rate with this protocol is 2-5% compared 30-40% for treadmill testing.
 - Drug of choice for patients on beta-blockers.

Persantine / Adenosine - Contraindications

- Persantine allergy
- **History of bronchospastic disease**
- Hypotension
- Hypertension (**sbp>200, dbp>110**)
- Wheezing
- Theophylline allergy
- **Definite unstable angina**
- CHF
- **2nd or 3rd degree heart block**
- Caffeine **within 12 hours**
- Xanthine drug (**theophylline**) **within 48 hours**
- **Severe or bilateral carotid artery disease**
- **Moderate to severe aortic stenosis**

Persantine stress testing

- Dose = 0.142 mg/kg/min IVPB for 4 minutes
- Common reactions:
 - Dizziness
 - Nausea / vomiting
 - Flushing
 - Headache / parasthesias
 - Tachycardia
 - ECG abnormalities
- Serious reactions:
 - Hypotension, severe
 - Bronchospasm
 - Myocardial ischemia / infarction
 - Arrhythmias
- Treatment of adverse reactions:
 - **Severe** reactions - IV Aminophylline (250mg IVP)
 - **Mild** reactions - caffeine (ie a cup of coffee or cola)
 - Preferably a few minutes after isotope has been injected, or study may be falsely negative.

TABLE 4. Comparison of Exercise Testing and Add-Ons or Other Test Modalities

Grouping	No. of Studies	Total No. of Patients	Sensitivity, %	Specificity, %	Predictive Accuracy, %
Meta-analysis of standard exercise ECG	147	24 047	68	77	73
Excluding MI patients	41	11 691	67	74	69
Limiting workup bias	2	2350	50	90	69
Meta-analysis of exercise test scores	24	11 788			80
Perfusion scintigraphy	2	28 751	89	80	89
Exercise echocardiography	58	5000	85	79	83
Nonexercise stress tests					
Pharmacological stress scintigraphy	11	<1000	85	91	87
Dobutamine echocardiography	5	<1000	88	84	86
EBCT	16	3683	91	49	70

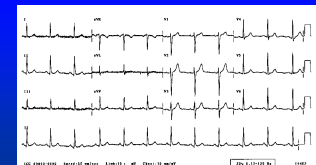
O'Rourke RA, et al. J Am Coll Cardiol 2000;36:326-40

A SUMMARY OF STRESS TEST SELECTION:

- **Exercise ECG:**
 - Ambulates well
 - Normal ECG
 - Lower probability of coronary ischemia
- **Exercise ECG with imaging (nuclear or echo):**
 - Ambulates well
 - Nonspecific or equivocal ECG changes
 - Moderate to higher probability of coronary ischemia
- **Persantine or adenosine nuclear study:**
 - Patient does not ambulate well
 - Pacemaker / LBBB
 - NO bronchospastic disease history
- **Dobutamine ECG alone or with imaging (nuclear or echo):**
 - Patient does not ambulate well and DOES HAVE bronchospastic disease history

Case #3

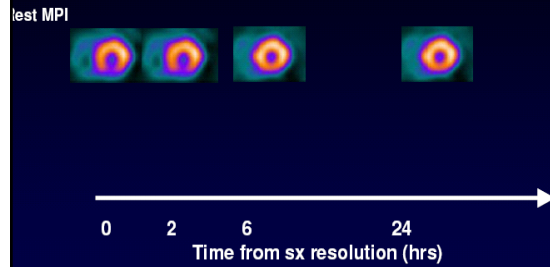
- 40 year old female diabetic smoker with left chest discomfort lasting 15 minutes following a heated argument with her teenage son. Hurts to breath and radiates to back. Only med is BCP.
- Normal exam
- Normal ECG



Why not simply get rest imaging?

- **Logistics**
- **Benefits**
- **Limitations**

Imaging Ischemia After Symptom Resolution

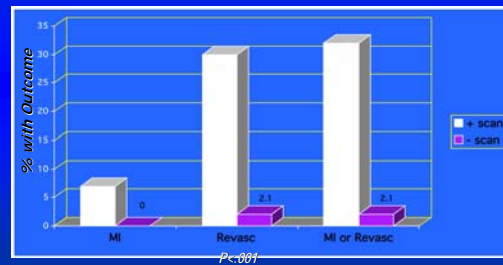


Timing of Sestamibi injection and imaging:

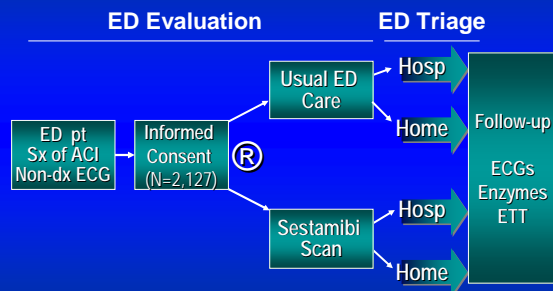
- “Stunned myocardium”
 - Abnormal uptake of sestamibi by ischemic myocardial cell membrane
 - Lasts roughly four hours from the time of resolution of ischemic pain
 - What about “silent” or painless ischemia???
- **Bottom Line: Can not trust NEGATIVE results if**
 - injection past 4 hours
 - Imaging past 4-6 hours

MCOV / Ornoto five track strategy Outcomes of Sestamibi Imaging @ 30 days

(Ann EM 1997;29:116-125)

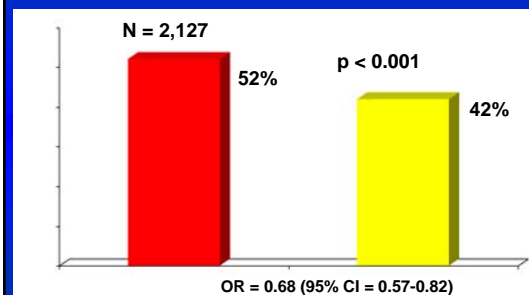


ERASE Chest Pain Trial: Study Design



Udelson et al. JAMA 2002;288:2693

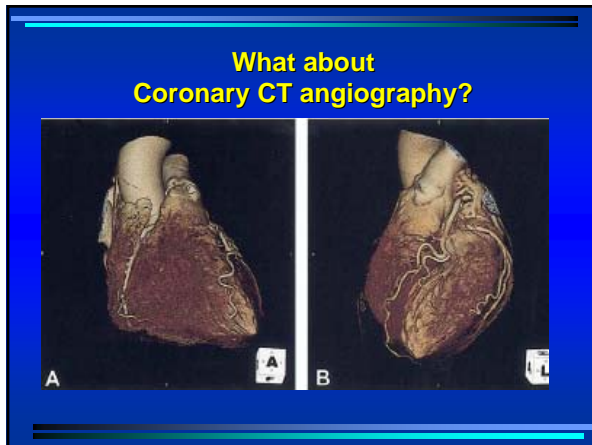
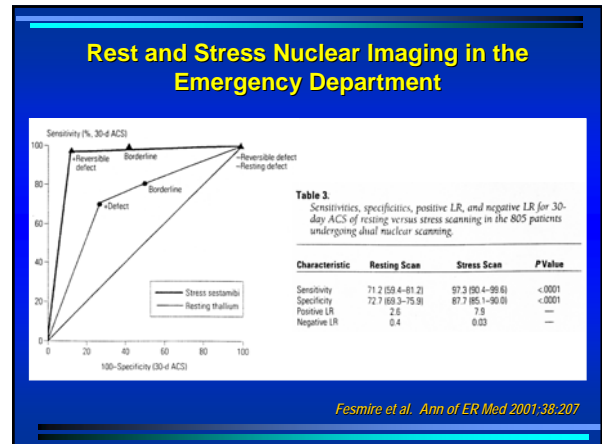
Effect of ED Sestamibi Imaging on Admissions in Patients Without ACI



Studies of REST sestimibi in the ED

Klocke et al. ACC/AHA/ASNC guidelines 2003

Author	Outcome	% Sens.	% Spec.	% PPV	% NPV
Bilodeau	CAD	96	79	94	86
Varetto	AMI	100	92	90	100
Tatum	MI	100	78	--	--
Heller	MI	90	60	12	81
Duca	MI	100	73	33	93
	CAD	73	93	89	100
Kontos	MI	92	67	47	--
	CAD	81	74	--	--
Hilton	MI/Death	94 / 100	83 / 78	--	--



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EXPRESS PUBLICATION

Diagnostic Accuracy of Noninvasive Coronary Angiography Using 64-Slice Spiral Computed Tomography

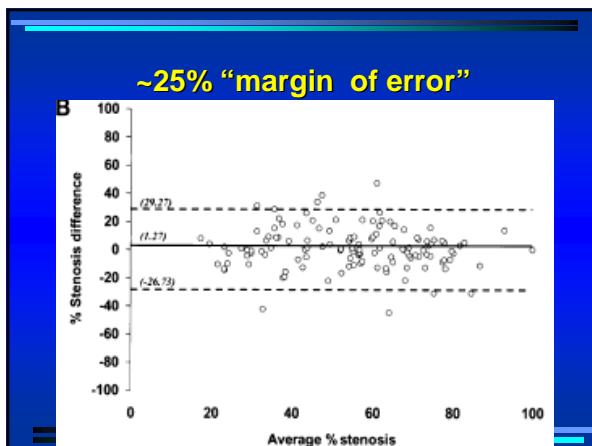
Gilbert L. Raff, MD, FACC, Michael J. Gallagher, MD, William W. O'Neill, MD, FACC, James A. Goldstein, MD, FACC

- 70 patients received both cardiac cath AND coronary CTA
- Cath used as gold standard

Table 2. Diagnostic Accuracy of Coronary MSCT Compared to QCA for Detection of Lesions >50% in Patients

	Sensitivity	Specificity	PPV	NPV
Patients (n = 70)	38/40 (95%)	27/30 (90%)	38/41 (93%)	27/29 (93%)
Arteries (n = 279)	63/69 (91%)	194/210 (92%)	63/79 (80%)	194/200 (97%)
Segments (n = 935)	79/92 (86%)	802/843 (95%)	79/120 (66%)	802/815 (98%)

Values are n (%). MSCT = multidetector computed tomography; NPV = negative predictive value; PPV = positive predictive value; QCA = quantitative coronary angiography.



CARDIOLOGY/ORIGINAL RESEARCH

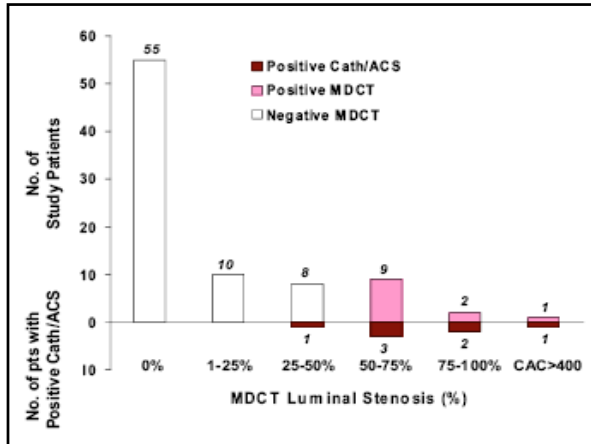
The Diagnostic Accuracy of 64-Slice Computed Tomography Coronary Angiography Compared With Stress Nuclear Imaging in Emergency Department Low-Risk Chest Pain Patients

Gallagher M, Ross MA, Raff G, et al. Ann Emerg Med. 2007;49:125-136.

- 92 ED Low risk chest pain patients
- All had Rest / stress sestimibi AND coronary CTA
- Surrogate clinical outcome or cath

Table 3. Myocardial perfusion imaging and multidetector CT accuracy (n=85).

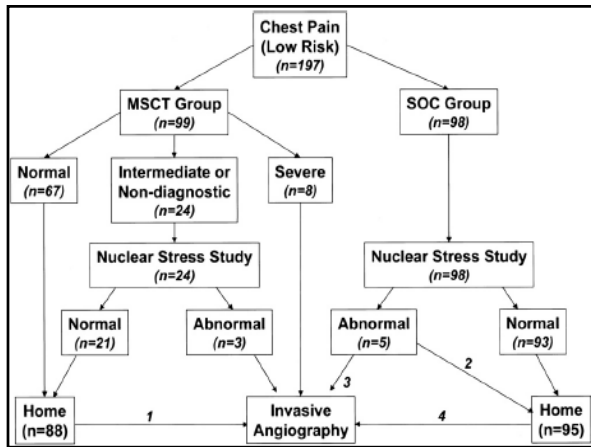
Imaging Method	Sensitivity (n)	Specificity (n)	PPV (n)	NPV (n)
Stress nuclear imaging (95% CI)	71% (5/7) (36%-92%)	90% (70/78) (81%-95%)	38% (5/13) (18%-64%)	97% (70/72) (90%-99%)
Multidetector CT (95% CI)	86% (6/7) (49%-97%)	92% (72/78) (84%-96%)	50% (6/12) (25%-75%)	99% (72/73) (93%-100%)



A Randomized Controlled Trial of Multi-Slice Coronary Computed Tomography for Evaluation of Acute Chest Pain

James A. Goldstein, MD, FACC, Michael J. Gallagher, MD, William W. O'Neill, MD, FACC, Michael A. Ross, MD, FACEP, Brian J. O'Neil, MD, FACEP, Gilbert L. Raff, MD, FACC

- 197 ED low risk chest pain patients were randomized:
 - Stress nuclear imaging
 - Coronary CTA



Outcomes:

- Turn around time:
 - Stress nuc = 15.0 hr
 - CTA = 3.4 hr
- Cost:
 - Stress nuc = \$1,872
 - CTA = \$1,586
- Double testing (CTA =>Stress nuc) = 25%
 - 15% - indeterminate stenosis
 - 10% - poor image quality (getting better)

What about Coronary Calcium Scoring? – PRO:

Coronary Artery Calcium Scoring in the Emergency Department: Identifying Which Patients With Chest Pain Can Be Safely Discharged Home

Rafael Pabst, MD From the Methodist Debbarth Heart and Vascular Center, The Methodist Hospital, Houston, TX

Coronary Artery Calcium Scoring for Chest Pain Patients *Nabe et al*

Table 3. Sensitivity, specificity and predictive values of SPECT and CACS for predicting all cardiac events.

Test Characteristics	SPECT (%)	95% CI	CACS (%)	95% CI	P Value
Sensitivity	20/32 (62.5)	43.7-78.3	30/32 (93.8)	77.8-98.9	.04
Specificity	970/999 (98)	96.9-98.7	623/999 (62.4)	59.3-65.4	.0001
PPV	20/40 (50)	34.1-65.9	30/400 (7.5)	5.1-10.5	—
NPV	979/991 (98.8)	97.8-99.3	623/625 (99.7)	98.7-99.9	—

PPV, Positive predictive value; NPV, negative predictive value.
 *CACS—dichotomized as normal (CACS=0) or abnormal (CACS>0).

Table 4. Studies examining the relationship between CACS and acute coronary syndrome in the ED setting.

Authors	Year	N	CACS=0 (%)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Lauton et al ¹⁰	1999	105	59 (56)	100	63	30	100
McLaughlin et al ¹¹	1999	134	48 (36)	100	38	8	100
Georgiou et al ¹²	2001	192	76 (40)	97	55	48	97
Hoffman et al ¹³	2009	368	197 (54)	97	59	18	99.8
Current study		1,031	629 (61)	93.8	62.4	7.4	99.7

*Based on no evidence of calcified plaque on CT coronary angiography.

Calcium Scoring – Con:

- Non-calcified plaque >75% = 18%
 - Rosen BD, et al. *J Am Coll Cardiol Imaging*. 2009;2:1175-1183
- Non-calcified plaque = 8%
 - Hoffman, et al. *J Am Coll Cardiol*. 2009;53:1642-1650

What about the "triple rule out"?

Triple-Rule-Out CT Angiography for Evaluation of Acute Chest Pain and Possible Acute Coronary Syndrome¹

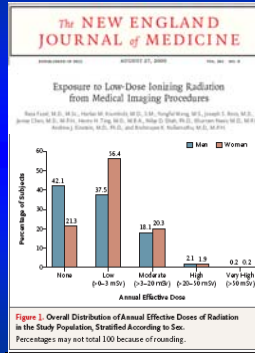
Halpern Radiology 25:2 2009

ORIGINAL PAPER
Coronary CT angiography in emergency department patients with acute chest pain: triple rule-out protocol versus dedicated coronary CT angiography

Hsin-Yuan Lee · Kyoung-Min Yoo · Charles S. White

- Rule out - ACS, PE, Dissection (or other path)
- Only low risk patients – no CAD, low prob PE/AD
- Technical issues – head-toe vs. toe-head
- More contrast
- More radiation
 - cCTA – men = 9-15 mSv
 - cCTA – women = 13-21 mSv

What about radiation?



Elements of Danger — The Case of Medical Imaging

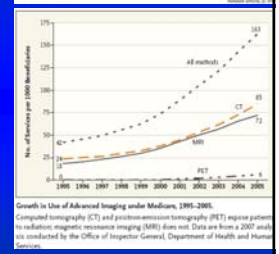


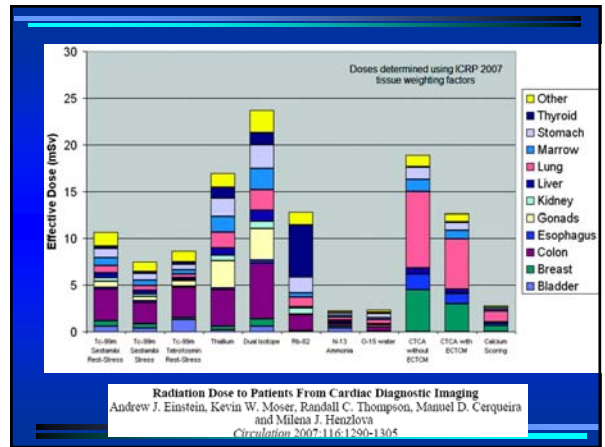
Figure 1. Overall Distribution of Annual Effective Doses of Radiation in the Study Population, Stratified According to Sex. Percentages may not total 100 because of rounding.

Units of Absorbed Dose								
Units not normalized by w_R	mGy	0.01	0.1	1	10	100	1,000	10,000
rad=100 Gy	rad=0.01 Gy	0.001	0.01	0.1	1	10	100	1,000
	Gy	0.00001	0.0001	0.001	0.01	0.1	1	10

Units of Effective Dose, Equivalent Dose, and Weighted Equivalent Dose								
Units normalized by w_R	mSv	0.01	0.1	1	10	100	1,000	10,000
rem=100 mSv	rem=0.01 mSv	0.001	0.01	0.1	1	10	100	1,000
	Sv	0.00001	0.0001	0.001	0.01	0.1	1	10

# of Chest x-rays (PA)	0.5	5	50	500	5,000	50,000	500,000
Average dose, atomic bomb survivors (BEER):							200 mSv
Annual limit to radiation workers (10 CFR 20.1201):							50 mSv
Dual isotope stress test:							29 mSv
Sentambi stress test or CTA with tube current modulation:							11 mSv
Average US annual background radiation:							3 mSv
Annual limit to general public from a licensed radiation operation (10 CFR 20.1301):							1 mSv
Chest x-ray (lateral) or Dental x-rays (4 bitewing films):							0.04 mSv
Roundtrip flight, New York-Los Angeles:							0.03 mSv
Chest x-ray (single view, posteroanterior):							0.02 mSv

Radiation Dose to Patients From Cardiac Diagnostic Imaging
 Andrew J. Einstein, Kevin W. Moser, Randall C. Thompson, Manuel D. Cerqueira and Milena J. Henzlova
Circulation 2007;116:1300-1305



What about costs?

Table 1. Estimated Costs of Common Cardiac Imaging Procedures and Other Laboratory and Office Visit Costs Using Published and Available Data Sources

	Average Cost (in U.S. \$)	Cost Range ± Add-ons* (in U.S. \$)
Imaging modalities		
Ankle brachial index	61	(40-64)
Carotid ultrasound	71	(62-77)
EPI/CT coronary calcium†	87	(62-90)
Treadmill exercise stress	67	(35-114)
Rest echocardiography	91	(64-342)
Other computed tomography	283	(90-475)
Magnetic resonance imaging	873	(525-1,220)
Positron emission tomography	1,272	(960-1,470)
Single-photon emission tomography	296	(262-574)
Right/left heart catheterization	1,810	(851-4,741)
Intravascular ultrasound‡	712	(NA)
Comparative costs		
Outpatient office visit§	39	(14-77)
Cholesterol panel	13	(10-22)
High sensitivity C-reactive protein	13	(8-20)
Advanced lipid analysis‡	247	(170-299)

EBT/CT = electron beam tomography/computed tomography.
 *Including contrast or radiopharmaceutical use and technique add-ons (e.g., wall motion). Cost data derived from Refs. 6, 9, 75-79.
 †Costs based on a brief report by Herington et al. (62) and from direct cost estimates by Shaw et al. (9).
 ‡Added cost of PUS was based upon the U.K. National Health Service health technology assessment by Berry et al. (5). Cost includes equipment and added labor for the United Kingdom and would be expected to vary in other health care systems. Costs are in U.S. dollars.
 §Costs are based on a brief report by Herington et al. (62) and from direct cost estimates by Shaw et al. (9).

Summary

- Know how to select and interpret testing
- Know when to suspect a false negative
- Live long and play hard